

[CONTRIBUTION FROM SOUTHERN REGIONAL RESEARCH LABORATORY]¹The Infrared Spectra of Gossypol^{1a}

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RECEIVED JANUARY 30, 1953

Infrared spectra of chloroform solutions of gossypol, 13 derivatives and degradation products of gossypol, and 18 "model" compounds containing groupings present in the gossypol molecule, have been obtained in the region from 2 to 12 μ . From wave length positions of observed maxima, correlations have been made with vibrating groups giving rise to the most prominent bands in the spectra. The infrared spectra confirm the fact that gossypol is an aromatic and phenolic compound. Correlation also confirms the presence of a carbonyl *ortho* to a hydroxyl group and in some derivatives of gossypol the presence of no carbonyl groups, and of carbonyl groups attached directly to an alicyclic grouping in others. The infrared spectra thus strongly support the chemical evidence that gossypol occurs in tautomeric forms. These observations are in agreement with the accepted structure of the gossypol molecule described by Adams, *et al.* However, no evidence was obtained from the infrared spectra regarding the binaphthyl character of gossypol. Hence, evidence for the binaphthyl group remains, as far as spectrophotometry is concerned, with ultraviolet spectra. No evidence was obtained from the infrared data for the presence of an isopropyl group. The correlations between the infrared spectra and chemical groupings in the molecules of gossypol and its derivatives provide a basis for following by infrared absorption the changes occurring in these and related compounds encountered in research on cottonseed and cottonseed products.

In all research on cottonseed and cottonseed products, the yellow pigment, gossypol, has required considerable attention. It creates many problems in processing the seed because it lowers the quality of the meal used for animal feeding, and when extracted with the oil is responsible for color reversion. For these reasons, intensive research has been conducted on the properties and reactions of gossypol.

During the 1937 to 1941 period, Adams and his students² described many reactions of gossypol and its products. They reported the structural formula to be 2,2'-bi-1,6,7-trihydroxy-3-methyl-5-isopropyl-8-aldehydonaphthyl, which is capable of existing in three tautomeric modifications. This formula is generally accepted.

Although Zamyshlyayeva and Krivich³ reported the infrared spectra of gossypol and gossypol derivatives and commented on some general relationships between observed absorption bands and groups in these compounds, no subsequent investigation of the infrared spectra of gossypol seems to have been made.

The purpose of this paper is to present the infrared spectra of chloroform solutions of gossypol and of several of its derivatives and degradation products in the spectral range 2–12 μ . Data are also given for the comparison of the absorption spectra of gossypol and gossypol derivatives with those of simpler model compounds and for the interpretation of the specific groupings giving rise to the observed absorption bands to provide a basis for the application of infrared data in research on the properties and reactions of gossypol.

Experimental

Infrared spectra were obtained with a Beckman IR-2T Recording Infrared Spectrophotometer⁴ housed in a room maintained at about 74°F. and 20% relative humidity.

(1) One of the laboratories of the Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture. (a) Presented at the Eighth Southwest Regional Meeting of the American Chemical Society, Little Rock, Arkansas, December 4–6, 1952. Article not copyrighted.

(2) (a) R. Adams, *et al.*, THIS JOURNAL, **59**, 1723, 1729 (1937); (b) **60**, 2158 (1938); (c) **60**, 2967 (1938); (d) **61**, 1132 (1939); (e) **63**, 528 (1941); (f) **63**, 535 (1941).

(3) A. M. Zamyshlyayeva and S. S. Krivich, *J. Gen. Chem. (U.S.S.R.)*, **8**, 319 (in English 329) (1938).

(4) Mention of the names of firms or trade products does not imply that they are recommended or endorsed by the U. S. Department of Agriculture over other firms or similar products not mentioned.

The temperature of the instrument was maintained at 25 \pm 1° by water circulating from a constant temperature bath. The spectrophotometer was calibrated against various liquids of known infrared properties obtained from the National Bureau of Standards.

All samples were measured in chloroform solution against the chloroform solvent in the same 0.4-mm. cell and at concentrations ranging from 4 to 36 g./l. with the following exceptions: diaminogossypol, 1.17 g./l. measured in a 2-mm. cell; acetylsalicylaldehyde in 0.4-mm. and 2-mm. cells; and phloroglucinol in Nujol mull against Nujol.

Preparation of Samples.—Some of the compounds used in these studies were prepared by methods already reported in the literature or were purified from commercial samples. Their physical constants and analyses agreed with those already published. The following noteworthy exceptions, whose preparations or properties have either not been previously reported or differ in some respect, will be described briefly. Analytical data will be given only for those compounds for which values have not been reported in the literature.

White and Yellow Gossypol Hexaacetates.—The separation of these two tautomers could be effected by a difference in their solubilities in cold methanol. Both hexaacetates were obtained in crystalline form, the white hexaacetate crystallizing out as boat-shaped crystals, m.p. 283–286°, and the yellow form as irregularly shaped crystals, m.p. 188–192°. The white hexaacetate previously reported⁶ melted at 276–279° and the yellow form was never before obtained in crystalline form.

Gossypol Hexamethyl Ethers.—The method of Von der Haar and Pominski⁶ was followed with some modification in the purification procedure. Two hexamethyl ethers could be separated from a methanol solution of the crude product. The less soluble ether, upon recrystallization from acetone and methanol, was obtained in very small amount in the form of colorless rectangular prisms, m.p. 220–222°. The more soluble form was obtained in much larger amount than the white form and, when repeatedly recrystallized from dilute methanol, yielded pale yellow spheres, m.p. 160–162°.

On acidulation of a hot methanol solution of the latter pale yellow ether with concentrated hydrochloric acid, dilution with water and cooling slowly, a violet form of gossypol hexamethyl ether was obtained in the form of small spheres, m.p. 146–148°.

Anal. Calcd. for C₃₀H₂₄O₅(OCH₃)₆: C, 71.7; H, 7.03; OCH₃, 30.9. Found: C, 72.0; H, 7.17; OCH₃, 33.3; ash, none.

Anhydrogossypol.—The method of Clark⁷ for the preparation of anhydrogossypol was followed with the modification that the temperature of the heated gossypol was not allowed to exceed 170–175° to facilitate isolation of the product.

Gossypolmonoisoprene.—The addition of isoprene to gossypol was effected by refluxing a solution of 5 g. of gossy-

(5) Reference 2a, p. 1730.

(6) P. Von der Haar and C. H. Pominski, *J. Org. Chem.*, **17**, 177 (1952).

(7) E. P. Clark, *J. Biol. Chem.*, **75**, 725 (1927).

pol in 125 ml. of absolute ethanol with 7.5 ml. of redistilled isoprene for 16 hr. The crude adduct obtained by concentration of the above solution was recrystallized several times from hot petroleum ether (b.p. 60–70°), discarding each time any insoluble material until a product of constant properties was obtained consistently. This product proved to be the mono-adduct in spite of the fact that gossypol tends to form di-adducts.⁸ The pure gossypolmonoisoprene crystallized as orange octagonal prisms, m.p. 170–172°.

Anal. Calcd. for C₄₀H₄₂O₆ (diisoprene adduct): C, 77.6; H, 6.84. Calcd. for C₃₅H₃₈O₇ (monoisoprene adduct): C, 73.9; H, 6.38. Found: C, 74.3; H, 6.54; ash, none.

Gossypoldiphenylhydrazone.—This gossypol derivative was prepared by treating gossypol with phenylhydrazine hydrochloride in a solution of sodium acetate. Recrystallization from dilute ethanol produced yellow hexagonal prisms, m.p. 187–189°. Elemental analysis of this compound is in agreement with the presence of two moles of solvent of crystallization to every mole of gossypoldiphenylhydrazone.

Anal. Calcd. for C₄₂H₄₂O₆N₄·2C₂H₅OH: C, 69.8; H, 6.88; N, 7.08. Found: C, 69.6; H, 6.72; N, 7.04; ash, none.

2,2'-Dihydroxy-3,3'-diacetoxy-1,1'-binaphthyl.—One gram of the dihydroxydicarboxybinaphthyl, prepared according to the method of Stanley and Adams,⁹ was esterified by refluxing with 150 ml. of absolute ethanol for 6 hours, allowing a slow stream of dry hydrogen chloride to pass through the system. The pale yellow ester separated upon concentration of the reaction mixture followed by addition of sodium carbonate until slightly alkaline. Recrystallization from ethyl acetate yielded greenish-yellow prisms, m.p. 231–232°.

Anal. Calcd. for C₂₆H₂₂O₆: C, 72.5; H, 5.12. Found: C, 71.8; H, 5.31; ash, none.

Infrared Spectra

The infrared spectra¹⁰ of gossypol, 13 derivatives and degradation products of gossypol, and 18 compounds of known structure which contain a grouping or groupings similar to those accepted as present in gossypol are shown in Figs. 1–4.

The three tautomeric forms of gossypol, according to Adams, *et al.*,¹¹ are shown in Fig. 5.

Band at 2.8 μ —Free Phenolic O–H Stretching Vibration.—A comparable band is observed in the spectra of phenol, di- β -naphthol and salicylaldehyde. Coggeshall¹² has studied the infrared absorption of phenolic O–H groups and has shown that position of maximum is dependent on the degree of hydrogen bonding, varying from about 2.7 μ to above 3.0 μ with increasing hydrogen bonding. Because of this bonding intensities of these bands do not follow Beer's law and no critical comparison of them can be made. However, if the magnitude of the intensity of the phenolic group be taken very roughly as $\epsilon = 40$, phenol and salicylaldehyde with one –O–H group and di- β -naphthol with two –O–H groups are in rough agreement. Gossypol, $\epsilon = 254.8$, would then contain six phenolic –O–H groups, as indicated by chemical data.

The band disappears on methylation, ethylation or acetylation (anisole, phenetole and acetylsalicylaldehyde). It is completely absent in the spectra of the gossypol hexaacetate or hexamethyl ethers but, as might be predicted, observed, at a reduced intensity, in the spectra of the dimethyl ether and

in that of anhydrogossypol. In the spectra of diamino- and dianilino-gossypol, an N–H stretching vibration would be unresolved in the present measurements, from the free O–H stretching (aniline and ethylamine).

Assignment of this observed band at 2.8 μ in the spectrum of gossypol to a stretching vibration of the phenolic O–H group is in agreement with well-established chemical data that show gossypol to be a phenolic substance.¹³

Band at 3.3 μ —C–H Stretching Vibration.—C–H stretching in saturated aliphatic compounds gives rise to a band at about 3.4 μ and in phenyl rings at about 3.25 μ .^{14,15} With the resolution possible in the measurement reported here, these two stretching vibrations might not be resolved from the variously reported C–H stretching of methyl, methylene and other groups and appear as a single band. The wave length maximum observed in the spectrum of gossypol at 3.28 μ , however, is, being less than 3.4 μ , an indication of aromatic character. Highly bonded O–H stretching would also be unresolved from the C–H stretching vibration,^{14,15} as has been established for the spectra of long-chain fatty acids,¹⁶ and might be expected to increase the intensity especially in more concentrated solutions.

Band at 6.2 μ —C=O Carbonyl Stretching Vibration.—Carbonyl C=O stretching gives rise, usually, to a band with maximum between 5.6 and 5.9 μ , depending on the nature of the carbonyl group. Grove and Willis¹⁷ have studied in detail the wave length positions, between 5.6 and 5.9 μ , of carbonyl groups in various molecules. In the spectra of gossypol no band was found in the 5–6 μ region in spite of the chemical evidence for the aldehyde or ketone group.

Josien and Fuson¹⁸ have commented on the shifted position of the infrared absorption bands assigned to C=O stretching in cyclic ketones and have cited examples where this vibration gives rise to bands with the absorption maximum at 6.10 μ . At this wave length the band might be unresolved from the weaker C=C stretching between 6.15 and 6.30 μ .¹⁴ The C=C stretching can be observed in the spectra of phenol, 6.28 μ ; benzyl alcohol, 6.25 μ ; and the binaphthyl, 6.20–6.30 μ .

The spectra of quinone and 1,4-naphthoquinone exhibit bands with maxima at 5.98 and 5.95 μ , respectively, attributed to C=O stretching. In the latter compound the C=C stretching band with maximum at 6.12 μ is also observed. That a quinone or a cyclic ketone group is not required for the C=O stretching vibration to be shifted above 6.0 μ is demonstrated by the spectrum of salicylaldehyde, which exhibits an intense band at 6.02 μ . Evidently when the carbonyl group is *ortho* to a hydroxyl group, the C=O stretching vibration is

(13) C. H. Boatner, "Pigments of Cottonseed in Cottonseed and Cottonseed Products," Edited by A. E. Bailey, Interscience Publishers, Inc., New York, N. Y., 1948, Chap. VI, pp. 213–363.

(14) R. B. Barnes, R. C. Gore, R. W. Stafford and V. Z. Williams, *Anal. Chem.*, **20**, 402 (1948).

(15) Jean Lecomte, "Traité de Chimie Organique," Vol. II, Part I, Edited by V. Grignard, Masson et Cie., Paris, 1941, pp. 143–293.

(16) R. T. O'Connor, E. T. Field and W. S. Singleton, *J. Am. Oil Chemists' Soc.*, **28**, 154 (1951).

(17) J. F. Grove and N. R. Willis, *J. Chem. Soc.*, 877 (1951).

(18) M. L. Josien and Nelson Fuson, *THIS JOURNAL*, **73**, 478 (1951).

(8) Reference 2b, p. 2161.

(9) W. M. Stanley and R. Adams, *Rec. trav. chim.*, **48**, 1035 (1929).

(10) All spectroscopic terms used throughout this paper are in conformity with the "Suggested Nomenclature in Applied Spectroscopy," *Anal. Chem.*, **24**, 1349 (1952).

(11) Reference 2b, p. 2194.

(12) N. D. Coggeshall, *THIS JOURNAL*, **69**, 1620 (1947).

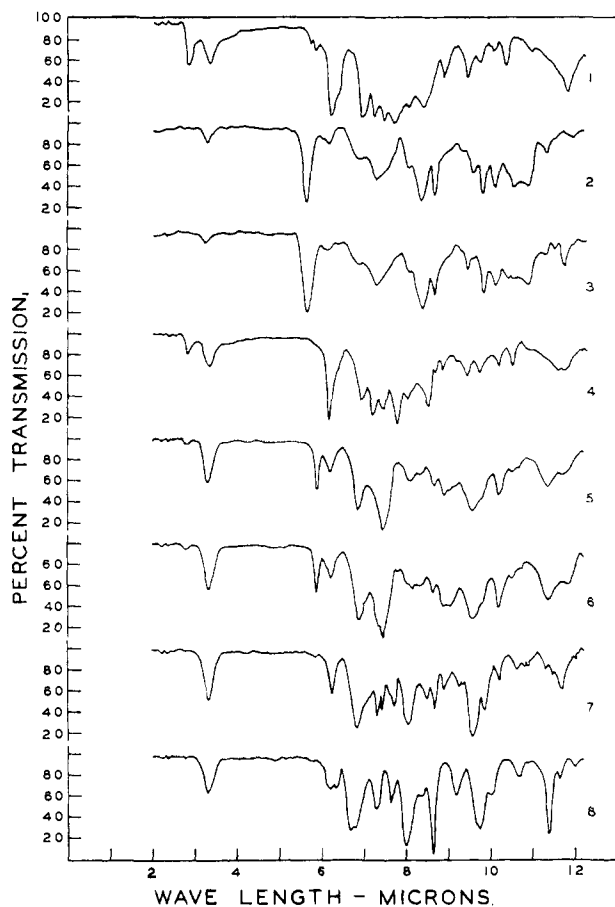


Fig. 1.—Infrared spectra of: 1, gossypol; 2, gossypol hexaacetate (white); 3, gossypol hexaacetate (yellow); 4, gossypol dimethyl ether; 5, gossypol hexamethyl ether (pale yellow); 6, gossypol hexamethyl ether (violet); 7, apogossypol hexamethyl ether; 8, desapogossypol hexamethyl ether (in chloroform solution).

shifted above 6.0μ . As there is no evidence of a band due to $C=C$ stretching, this vibration must be unresolved from the $C=O$ stretching. Conjugation of the $C=O$ with an aromatic ring is not sufficient to shift the $C=O$ stretching vibration above 6.0μ . For example benzaldehyde has an intense band at 5.87μ and Grove and Willis¹⁷ assign this identical band (5.87μ) to the position of maximum characteristic of aromatic aldehydes.

The spectrum of gossypol in chloroform solution (Fig. 1) resembles that of salicylaldehyde more closely than that of the quinones, with a single intense band at 6.18μ . This longer wave length position of maximum compared to the 6.02μ band in the spectrum of salicylaldehyde is compatible with the greater degree of conjugation. The $C=O$ carbonyl group conjugated to the naphthalene nucleus on the 1- or 2-position should be expected to produce a greater bathochromic shift when compared to conjugation with the benzene ring. This is illustrated chemically by the ability of $CH_2=CH-C_{10}H_7$, with an identical conjugated system, to undergo a Diels-Alder reaction while the corresponding $CH_2=CH-C_6H_5$ will not. This structure is in agreement with the tautomeric form No. 1 of

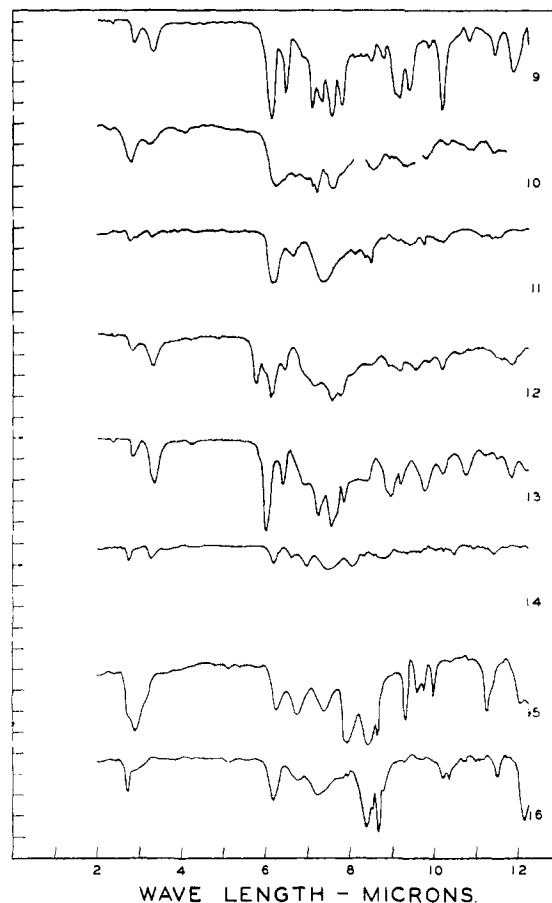


Fig. 2.—Infrared spectra of: 9, anhydrogossypol; 10, diaminogossypol; 11, dianilinogossypol; 12, gossypolmono-isoprene; 13, gossypoldi-2,3-dimethylbutanediene-1,3; 14, gossypoldiphenylhydrazone; 15, phenol, 16, di- β -naphthol (in chloroform solution).

Adams and his students. This interpretation of the infrared structure is in conformity with the presence of an aldehyde group *ortho* to a hydroxyl group.

The spectra of the hexaacetates reveal only a weak band at 6.10μ and a strong band at 5.62μ . This latter band is obviously to be correlated with the normal $C=O$ stretching vibration of the ester group. The 6.10μ band may be either the weak $C=C$ stretching vibration or this band unresolved from a very weak $C=O$ band arising from a $C=O$ stretching which has been shifted above 6.0μ as in the spectra of gossypol. In either case the intensity of the shifted $C=O$ stretching vibration has been greatly reduced in the spectra of the hexaacetates as compared to that of gossypol. This observation could be most easily accounted for by assuming that the hexaacetates exist mainly in tautomeric form No. 2 which has no carbonyl group. Such a conclusion is in agreement with chemical data which show that gossypol hexaacetate does not react readily with aldehyde reagents.¹⁹ In this connection it is interesting to compare the infrared

(19) C. H. Boatner, R. T. O'Connor, M. C. Curet and C. S. Samuels, *THIS JOURNAL*, **69**, 1268 (1947).

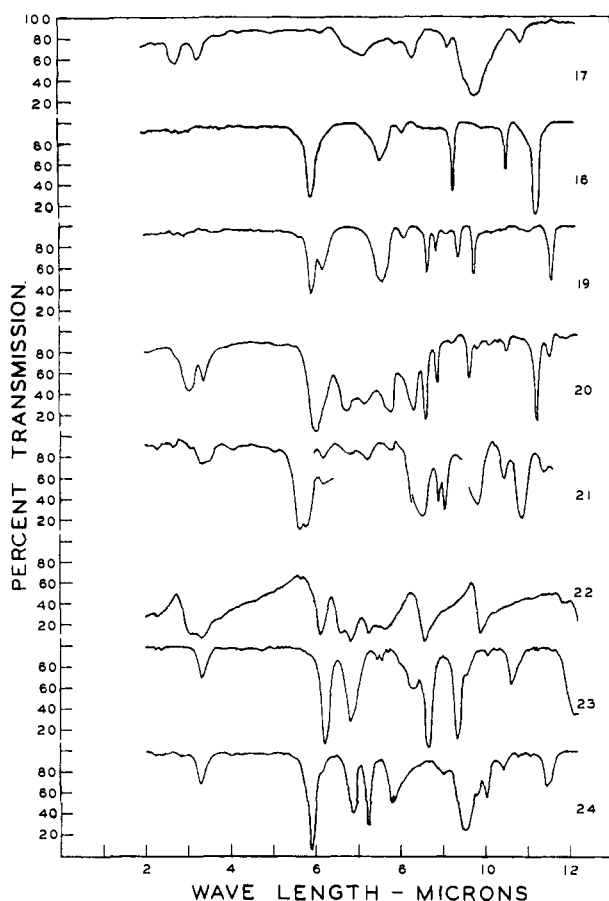


Fig. 3.—Infrared spectra of: 17, benzyl alcohol; 18, quinone; 19, 1,4-naphthoquinone; 20, salicylaldehyde; 21, acetylsalicylaldehyde; 22, phloroglucinol; 23, trimethylphloroglucinol; 24, hexamethylphloroglucinol (in chloroform solution—except phloroglucinol in Nujol mull).

spectra of acetylated salicylaldehyde (Fig. 3). Unlike acetylated gossypol, acetylsalicylaldehyde exhibits bands at 5.65μ , normal C=O ester stretching vibration, at 5.80μ , normal aromatic aldehyde stretching, and at 6.10μ the C=C stretching vibration. The spectrum is exactly that which would be expected upon acetylation. The shifting of the aldehyde C=O maximum back to the normal position for aromatic aldehydes, 5.80μ , as the O-H *ortho* to it is removed, is further evidence that this relationship is responsible for the original shifting of this band above 6.0μ . The changes in the spectra of gossypol, upon acetylation, appear to indicate that more than merely substitution of acetyl groups has occurred or in other words that this process has been accompanied by a tautomeric shift in the molecular structure from form No. 1 to form No. 2 (Fig. 5).

Ethers exhibit C-O-C stretching vibrations at about 9.0μ and no prominent bands in the 6.0μ region.¹⁴ The dimethyl ether of gossypol exhibits spectra with band maxima at 6.18 and 6.35μ . The 6.35μ band will be discussed later. The 6.18μ band is attributed to the C=O stretching vibration shifted by the presence of a hydroxyl group *ortho* to the carbonyl. Gossypol dimethyl ether

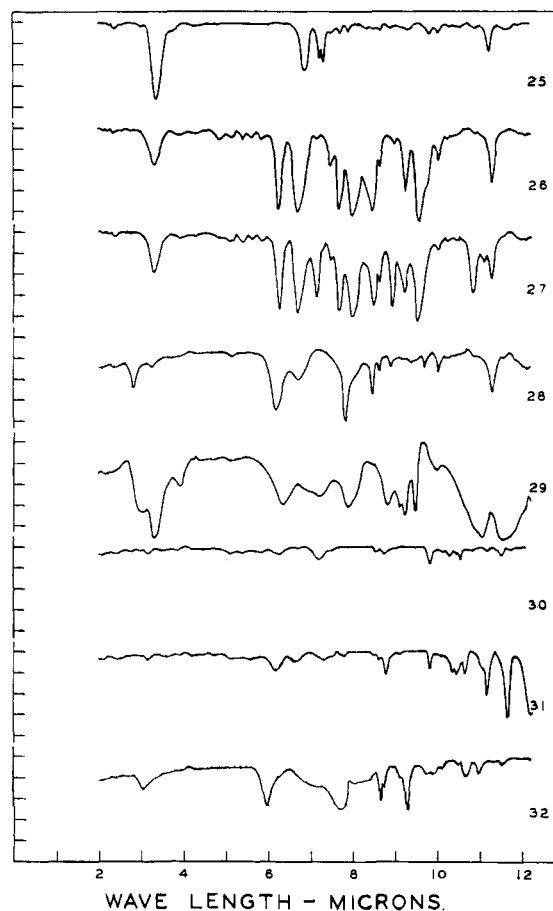


Fig. 4.—Infrared spectra of: 25, isopropylcyclohexane; 26, anisole; 27, phenetole; 28, aniline; 29, ethylamine; 30, 1,1'-binaphthyl; 31, 2,2'-binaphthyl; 32, 2,2'-dihydroxy-3,3'-diacetoxy-1,1'-binaphthyl (in chloroform solution).

then has the same tautomeric structure as gossypol, form No. 1, a conclusion compatible with its chemical properties and ultraviolet spectra. The methylation does not take place on the hydroxyl group *ortho* to the carbonyl. This last observation is in agreement with that of Adams and Geissman²⁰ from chemical data.

The spectra of the hexamethyl ethers exhibit bands at 5.88 and 6.22μ and thus resemble the spectra of quinone and 1,4-naphthoquinone. The 5.88μ band may be attributed to the stretching of the C=O on the alicyclic ring and the 6.15μ band to C=C stretching of the tautomeric form No. 3 (Fig. 5). Such a structure would be expected to exhibit an infrared spectra resembling that of a quinone. An alternate interpretation would be that the 5.88μ band is the normal aromatic aldehyde (as the *ortho* O-H is removed) and the 6.15μ micron band the weak C=C stretching. The first conclusion only is in agreement with the chemical evidence that the hexamethyl ether of gossypol does not react with reagents like ammonia and aniline²¹ and it is compatible with the marked change in ultraviolet spectra of the gossypol hexamethyl ethers

(20) Reference 2b, p. 2163.

(21) Reference 2b, pp. 2163, 2166.

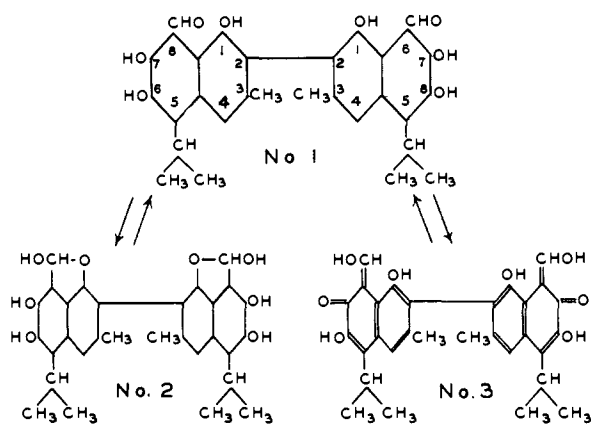


Fig. 5.—Three tautomeric forms of gossypol as proposed by Adams, *et al.*

as compared to that of gossypol. In the ultraviolet spectra of the hexamethyl ethers the characteristic structure of an aromatic group which has been used to support the postulation that gossypol is a binaphthyl²² is completely lacking.

The infrared spectra of anhydrogossypol resembles that of gossypol with a single intense band at 6.12μ and thus seems to exist in chloroform solution in tautomeric form No. 1, although Adams and his co-workers decided that its chemical reactions could best be explained by assuming form No. 3 for this compound.²³ An intense band is exhibited in the spectra of anhydrogossypol at 6.45μ . This band has not been identified. It is interesting to note that Randall, Fowler, Fuson and Dangl report a band at 6.54μ which they were unable to identify in compounds which did not contain nitrogen.²⁴ This band is exhibited also in the spectra of gossypol dimethyl ether and desapogossypol hexamethyl ether.

Apogossypol is prepared by the removal of the aldehyde groups from gossypol by the action of hot concentrated alkali. The hexamethyl ether of this compound has no carbonyl group, and in the 6.0μ region its infrared spectra exhibits only the weak C=C stretching vibration band at 6.25μ . Similarly, desapogossypol, a further degradation product of gossypol prepared by removal in addition to the aldehyde groups of the isopropyl group by action of cold concentrated sulfuric acid, has no carbonyl group. Its infrared spectra reveal no bands in the 6.0μ region other than the weak 6.25μ C=C stretching vibration band. This compound also exhibits a 6.42μ band, unidentified, but similar to that found in the infrared spectra of anhydrogossypol.

Diamino- and dianilinogossypols reveal spectra with very intense bands at 6.25 and 6.22μ , respectively. These bands are attributed to unresolved C=C and C=N stretching vibrations, of tautomeric form No. 1 or possibly No. 3.

Gossypoldiphenylhydrazone has a single less intense band at 6.20μ which similarly can arise from unresolved C=C and C=N stretching vibrations.

(22) Reference 2b, p. 2180.

(23) Reference 2b, p. 2195.

(24) H. M. Randall, R. G. Fowler, Nelson Fuson and J. R. Dangl, "Infrared Determination of Organic Structures," D. Van Nostrand Co., Inc., New York, N. Y., 1949.

Bands at 7.0 , 7.4 and 7.6μ , C-H Bending and CH₃ Deformation.—In the region 7.0 to 7.6μ , three bands, which probably arise from bending vibrations, are exhibited by most of the compounds studied. A band about 7.20 is attributed to a C-H bending vibration and bands about 7.1 and 7.6μ arise from CH₃ deformation vibrations.

Infrared evidence for the terminal isopropyl group would be of particular interest. The most reliable evidence for a terminal isopropyl group appears to be the splitting of a band arising from C-CH₃ bending at about 7.25μ into two components of about equal intensity.^{14,25} The reliability of this absorption for various types of compounds is shown in Table I, where spectral data at about 7.25μ for aliphatic, alicyclic and aromatic compounds are compared with their normal propyl and their isopropyl derivatives. These data, from A.P.I. curves, illustrate that the splitting is a reliable source of evidence for isopropyl groups in several types of organic compounds.

TABLE I
INFRARED SPECTRA—BAND AT 7.25μ

Compound	Band max, λ
<i>n</i> -Hexane	7.24
2-Methylhexane ^a	7.22–7.30
2,5-Dimethylhexane ^a	7.22–7.31
Cyclopentane
<i>n</i> -Propylcyclopentane	7.23
Isopropylcyclopentane ^a	7.22–7.31
Cyclohexane
<i>n</i> -Propylcyclohexane	7.25
Isopropylcyclohexane ^a	7.21–7.29
Benzene
<i>n</i> -Propylbenzene	7.24
Isopropylbenzene ^a	7.22–7.33
1,2-Diisopropylbenzene ^a	7.23–7.32
1,3-Diisopropylbenzene ^a	7.25–7.34
1,4-Diisopropylbenzene ^a	7.25–7.35

^a These compounds contain isopropyl groups.

However, inspection of the spectra of gossypol and its derivatives shows no evidence for isopropyl splitting. The question which first arises is whether or not in the present measurements sufficient resolution was obtained for the splitting to be observed. The spectrum of isopropylcyclohexane was determined to verify this point and it (Fig. 4) exhibits the two well defined bands.

In molecules as complicated as gossypol, subtle molecular environmental effects may negate the evidence for isopropyl splitting which has been shown to be reliable in the infrared spectra of simpler molecules.

A comparison of the bands found in this region in the infrared spectra of the hexamethyl ethers of gossypol and of apo- and desapogossypol is of some interest. These bands are compared in Table II.

These changes, especially the strong bands which appear in the spectra of desapogossypol, are difficult to correlate with the removal of a carbonyl or an isopropyl group.

Bands at 8.0 , 8.4 and 8.8μ —C-O Stretching Vibrations.—The infrared spectra of oxygen con-

(25) N. B. Colthup, *J. Opt. Soc.*, **40**, 397 (1950).

TABLE II
COMPARISON OF C-H BENDING VIBRATIONS OF HEXA-METHYL ETHERS

Hexamethyl ether of	Band maxima and intensities				
Gossypol	6.86 (385.3)				7.45 (517.7)
Apogossypol	6.82 (377.1)	7.03 (322.4)	7.32 (273.3)		7.43 (235.0)
Desapogossypol	6.67 (337.3)	6.80 (314.2)		7.33 (184.8)	7.63 (157.1)

taining compounds exhibit several strong bands in the 8μ region arising from stretching vibrations of the C-O group. Colthup²⁵ attributes bands with maxima in this region to aromatic ketones, aldehydes, alcohols, esters and ethers. These three bands exhibited in the spectra of gossypol could arise from C-OH²⁶ and Ph-C-H-O²⁵ groups as indicated by the structure of tautomeric form No. 1. Complete acetylation, and the structure of tautomeric form No. 2, would eliminate both of these sources of vibration in the spectra of the hexaacetates. The three bands observed, however, could easily be attributed to the triple C-O stretching vibrations of esters.²⁷ Similar assignments can be made for bands in this region exhibited by other derivatives of gossypol, but they are of little or no value to this study.

Bands above 9.0μ .—The infrared spectrum above 9.0μ has been called the "fingerprint" region as distinguished from the "group frequency" region below 9μ . Above 9μ the spectra begin to take on features characteristic of the particular molecule which make it particularly valuable for identification by direct comparison, but maxima characteristic of particular groupings become less well-defined.

About 9.4 – 9.5μ the C-O stretching vibration of

(26) Harris Rosenkrantz, *J. Biol. Chem.*, **173**, 439 (1948).

(27) O. D. Shreve, M. R. Heether, H. B. Knight and D. Swern, *Anal. Chem.*, **22**, 1498 (1950).

$\text{CH}_3\text{-C-OH}$ would account for the band in gossypol.^{28,29} At 9.6μ , O'Connor, *et al.*,¹⁶ showed evidence for a band due to the ester group and the C-O-C stretching vibration of aromatic ethers has been placed at about 9.5μ by Colthup.²⁰

Bands at 9.7 , 10.0 , 10.5 and 11.0μ are quite likely attributable to CH_3 bendings about various C=C groups.

Of particular interest to the study of gossypol is evidence concerning the presence of the binaphthyl grouping. The spectrum of gossypol has been compared with those of both 1,1'-binaphthyl and 2,2'-binaphthyl. The latter two compounds exhibit rather weak bands, due probably to their high degree of symmetry. 2,2'-Dihydroxy-3,3'-diacetoxy-1,1'-binaphthyl was prepared and its infrared spectrum measured. A comparison of the bands above 10.0μ is given in Table III. Considering the four bands exhibited by gossypol as its "fingerprint" it will be readily seen from the data in Table III that none of the compounds of known structure can be considered as matching it. However, none of these bands, probably, arise from the binaphthyl group. For evidence of binaphthyl it will be necessary, most likely, to study the spectra above 12μ in the potassium bromide region of the infrared.

TABLE III

COMPARISON OF BANDS IN THE "FINGERPRINT" REGION						
1,1'-Binaphthyl	9.82	10.30	10.55		11.55	
2,2'-Binaphthyl	9.82	10.45	10.65	11.18	11.65	12.20
2,2'-Dihydroxy-3,3'-diacetoxy-1,1'-binaphthyl	9.75		10.68	10.98	11.55	
Gossypol	9.72	10.05		10.95		11.82
		10.35				

(28) F. A. Smith and E. C. Creitz, *J. Research Natl. Bur. Standards*, **46**, 145 (1951).

(29) Earle K. Plyler, *ibid.*, **48**, 281 (1952).

NEW ORLEANS, LOUISIANA

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, UNIVERSITY OF TORONTO]

Cyclitols. VII. Debromination of Inositol Dibromohydrins. Synthesis of New Cyclohexanetetrols^{1,2}

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RECEIVED NOVEMBER 24, 1953

The dibromotetrol of m.p. 190° derived from inositol is shown to be 3,6-dibromocyclohexanetetrol-1,2,4,5 since on debromination it gives a 1,2,4,5-tetrol of m.p. 208° identical with one recently prepared by hydroxylation of 1,4-cyclohexadiene. The dibromocyclohexanetetrol of m.p. 216° , previously shown to have a 4,6-dibromo structure, on debromination gives a new 1,2,3,5-tetrol of m.p. 182° . Bromoviboquercitol-A can be converted into these two dibromotetrols but bromoscyloquercitol-A resists further bromination. Tentative assignments of configuration for these tetrols and for all of the known dibromo and diaminocyclohexanetetrols are proposed.

We recently reported⁴ that two bromocyclohexanepentols derived from *myo*-inositol can be catalytically debrominated to pentols (quercitols). We now find that two dibromocyclohexanetetrols, also prepared from inositol, can be debrominated in a similar manner, giving new cyclohexanetetrols.

(1) For the preceding paper in this series see G. E. McCasland and E. C. Horswill, *THIS JOURNAL*, **76**, 0000 (1954).

(2) From the Ph.D. Thesis of E. Clyde Horswill, 1953.

(3) Fellow of the National Research Council, 1952-1953.

(4) G. E. McCasland and E. Clyde Horswill, *THIS JOURNAL*, **75**, 4020 (1953).

Considerable progress has been made in elucidating the structure and the configuration of these compounds, which are important because of their relationship to the biologically active inositol and streptomycin.

